

Analysis of active flow control concepts Using the 3D LES

VorCat Software, Phase I Project

SBIR/STTR Programs | Space Technology Mission Directorate (STMD)



ABSTRACT

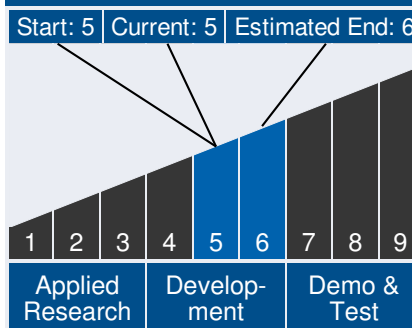
The goal of this project is to produce a revolutionary computational methodology that is fast, reliable and accurate for predicting complex high Reynolds number, turbulent flows associated with efficient aerodynamic designs. The proposed work will focus on low-speed canonical flows that introduce challenging physics, e.g., separation, transition and turbulence onset/progression, vortex/viscous interactions, merging shear layers with strong curvature, juncture flows, etc.. The extension of our proposed methodology to compressible flows has already begun and will be pursued in Phase II and beyond. The VorCat implementation of the gridfree vortex method is particularly attractive in this case since it efficiently represents near-wall vorticity producing motions while at the same time capturing the dynamics of the shed vorticity without numerical diffusion. An accurate and well resolved accounting of the boundary flow is crucial for controlling separation and other complex phenomena while unsteady free vortices are responsible for producing sound, downstream wing/vortex interactions and a range of other important phenomena. A number of previous published studies have established the unique benefits and accuracy of the VorCat vortex filament method. These include computations of ground vehicle flows, isotropic turbulence, shear layers, coflowing round jets, and boundary layers. Additional validation studies have been conducted in such applied settings as wind turbines, rotorcraft and particulate flows. Collectively, these results establish the effectiveness of the vortex filament scheme in capturing the flow structure and statistics for complex flow fields in a way that has not been duplicated by alternative grid-based methodologies. In the realm of vortex structure the VorCat approach has opened up a window into the dynamics of flow organization that is forcing a reassessment of some of the principal ideas concerning the physics of turbulent flow (J. Phys., 2011).



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Technology Maturity



Management Team

Program Executives:

- Joseph Grant
- Laguduva Kubendran

Program Manager:

- Carlos Torrez

Continued on following page.

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ANTICIPATED BENEFITS

To NASA funded missions:

Potential NASA Commercial Applications: This project brings to NASA a means for circumventing the persistent limitations of traditional turbulence modeling and simulation techniques that have delayed or prevented progress across a spectrum of innovative flow technologies. In particular, unlike RANS modeling, VorCat requires no ad hoc model adjustments that must be fine tuned to the peculiarities of individual flows or extensive three-dimensional grid development that often requires a posteriori refinements to reduce numerical diffusion and/or capture missing details of detached vortices. Unlike grid-based schemes, VorCat readily accounts for natural transition to turbulence without the use of special forcings. With VorCat, the door is opened for NASA to more freely pursue design innovations without heavy reliance on corroborating physical tests. Some particular examples where VorCat can have high impact both for NASA and global aerospace industry include aerodynamic efficiency and drag reduction through innovative active flow control mechanisms, aeroacoustics and structural analysis that relies on accurate CFD input data, vehicle design optimization, safety studies, and flows containing complex physics, turbulent mixing and heat transfer. When the compressible Vorcat version is developed and validated, possibly with the addition of more physics, it will be applied to compressible flow problems such as found in transonic, supersonic, and hypersonic flow regimes.

To the commercial space industry:

Potential Non-NASA Commercial Applications: Vorcat, Inc. has been very active in the commercial, non-NASA markets both in the US and abroad. Vorcat's focus in the commercial markets has been on reen/renewable energy applications, such that include the simulation and assessment of innovative hydro- and wind turbine concepts, the design, analysis and optimal placement of wind turbines in a wind farm and aerocoustics

Management Team (cont.)

Principal Investigator:

- Jacob Krispin

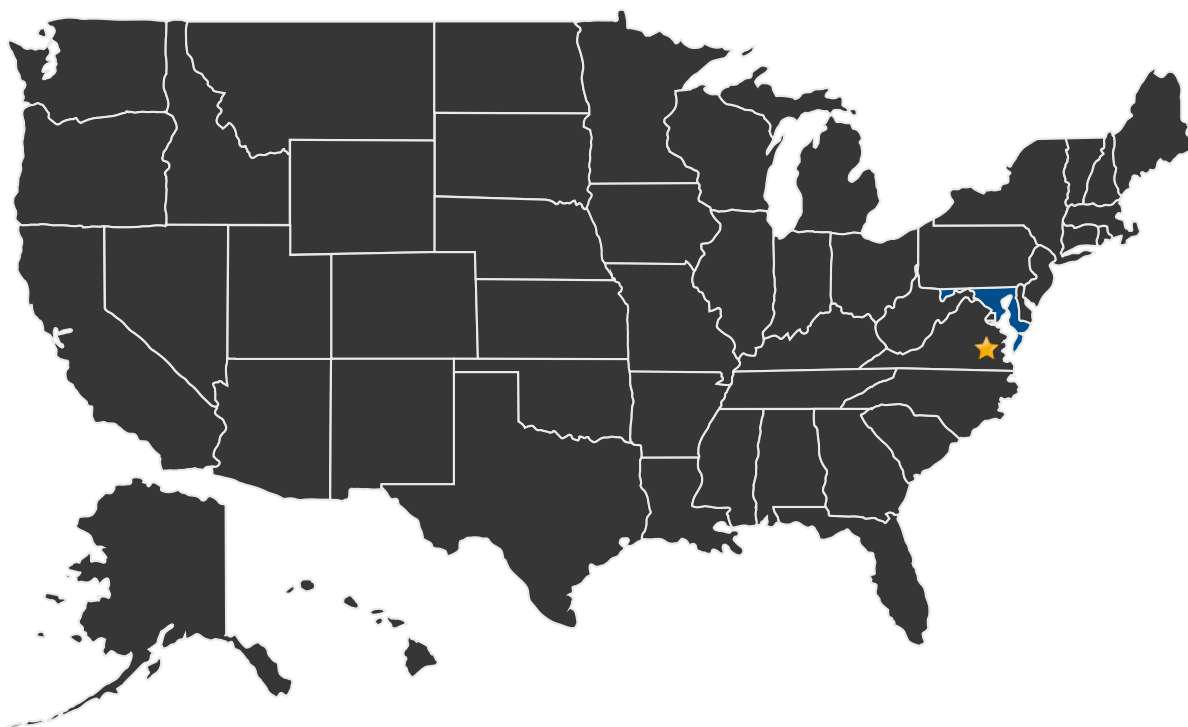
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analysis of wind farms; Applications in the automotive market include aerodynamics (and aeroacoustics) analysis and optimization of automotive shapes, simulations of automotive subsystems (HVAC, under carriage flows); Helicopter applications - both in the commercial world and DOD - include safety studies (landing on moving objects, hovering in the vicinity of obstacles, etc.), providing data to flight simulators for complex landing and hovering settings, etc. Pollution and chem/bio warfare scenarios which include turbulent mixing, particulate transport, collection of chemical agents by UAV, etc. There are numerous other commercial market niches where we can step in once this NASA project is completed.

U.S. WORK LOCATIONS AND KEY PARTNERS



■ U.S. States With Work

★ **Lead Center:**
Langley Research Center

Other Organizations Performing Work:

- VorCat, Inc. (Rockville, MD)

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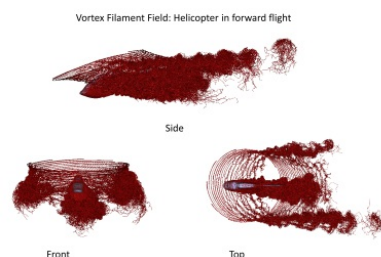


PROJECT LIBRARY

Presentations

- Briefing Chart
 - (<http://techport.nasa.gov:80/file/23128>)

IMAGE GALLERY



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DETAILS FOR TECHNOLOGY 1

Technology Title

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Potential Applications

This project brings to NASA a means for circumventing the persistent limitations of traditional turbulence modeling and simulation techniques that have delayed or prevented progress across a spectrum of innovative flow technologies. In particular, unlike RANS modeling, VorCat requires no ad hoc model adjustments that must be fine tuned to the peculiarities of individual flows or extensive three-dimensional grid development that often requires a posteriori refinements to reduce numerical diffusion and/or capture missing details of detached vortices. Unlike grid-based schemes, VorCat readily accounts for natural transition to turbulence without the use of special forcings. With VorCat, the door is opened for NASA to more freely pursue design innovations without heavy reliance on corroborating physical tests. Some particular examples where VorCat can have high impact both for NASA and global aerospace industry include aerodynamic efficiency and drag reduction through innovative active flow control mechanisms, aeroacoustics and structural analysis that relies on accurate CFD input data, vehicle design optimization, safety studies, and flows containing complex physics, turbulent mixing and heat transfer. When the

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